Opportunities and Challenges for Alternative Fuels

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Renewable Energy Indicators
As of Year End 2004

Power Generation
Existing Capacity* – GW

- Geothermal power 8.9
- Solar thermal power 0.04
- Solar PV, off-grid 2.2
- Solar PV, grid-connected 1.8
- Biomass power 39
- Ocean (tidal) power 0.03
- Wind turbines 48

Transport Fuels
Billion liters/year

- Ethanol production
- Biodiesel production
- Gasoline production

*Does not include hydropower

Source: REN21 Renewables 2005 Status Report,
Significance of the 1.3 Billion Ton Biomass Scenario

Based on ORNL & USDA Resource Assessment Study by Perlach et.al. (April 2005)
Biofuels

Biofuels status
• Biodiesel – 75 million gallons (2005)
• Corn ethanol
  – 81 commercial plants
  – 3.9 billion gallons (2005)
  – Today’s cost ~$1.35/gallon of gasoline equivalent (gge)
• Cellulosic ethanol
  – Projected commercial cost ~$3.00/gge

Potential
• 2012 goal – cellulosic ethanol ~$1.42/gge
• 2030 goal – all ethanol = 30% of transportation fuels

NREL Research Thrusts
• The Biorefinery
• Solutions to under-utilized waste residues
• Energy crops

Source: U.S. Department of Energy, National Biodiesel Board, Renewable Fuels Association
Building the Supply Chain

Biomass Feedstock Supply
Biomass Feedstock Transport
Biomass Conversion Technology
Markets: Fuels & Vehicles
Biomass Feedstock Supply
Renewable Waste Resources

Biomass Feedstock Transport
Ethanol Distribution Infrastructure Hurdles

- Estimate that E85 pumps will be required in 50% of U.S. service stations
  - Public policy support may be necessary to encourage investment

- E10 and E85 may enter U.S. pipeline system
  - E10 may move through product pipelines if they are modified to trap water, sediment and to keep ethanol from other products (diesel)
  - E85 dedicated pipelines will be created to connect large producing centers to large use centers

- E85 pumps may require new or modified underground tanks at retail outlets
Biomass Conversion Technology
Biochemical Conversion Barrier Areas

- **Feedstock Interface**
  - Pretreatment
    - Xylose yield
    - Xylose degradation
    - Solids loading
    - Reactor costs
  - Hydrolyzate Conditioning
    - Sugar loses
  - Enzymatic Hydrolysis
    - Glucose yield
    - Solids loading (titer)
  - Fermentation
    - Ethanol
      - Yields from all sugars
      - Concentration
      - Rate

- **Product Recovery**
  - Product
  - Byproducts
  - Residue Processing

- **Enzyme Production**
  - Enzyme cost

**Products**

**Byproducts**
Biomass Conversion Technology
Reducing the Cost of Ethanol from Stover

State of technology estimates

Minimum ethanol selling price ($/gal)

- Enzyme
- Conversion
- Current DOE cost targets
- President’s Initiative
- Costs in 2002$

Feed $53/ton

2005 yield 65 gal/ton

Feed $30/ton Yield 90 gal/ton

Feed $30/ton Yield 94 gal/ton

10,000 TPD

Biomass Conversion Technology
Thermochemical Conversion Barrier Areas

Feed Processing and Handling
- Size Reduction
- Storage and Handling
- De-watering
- Drying

Gasification and Pyrolysis
- Partial Oxidation
  - Air blown
  - Oxygen blown
  - Indirect
- Flash pyrolysis
- Steam pyrolysis
- Vacuum pyrolysis

Gas Cleanup
- Particulate removal
  - Tar reforming
  - Benzene removal
  - S, N, Cl mitigation
- High T Filtration
  - Alkali removal

Gas Conditioning
- Methane reforming
  - CO₂ removal
  - H₂/CO adjustment
  - Sulfur polishing
- Aerosol collection
  - Microfiltration
  - Chemical Stabilization
  - Hydrotreating
  - Dehydration

Fuel Synthesis
- C1 chemistry
  - FT liquids
  - MTG
  - Mixed OH
- Upgrading
- Production Separation

Heat & Power
Markets: Fuels & Vehicles
U.S. Transportation

<table>
<thead>
<tr>
<th></th>
<th>Autos</th>
<th>Light Trucks</th>
<th>Heavy Trucks</th>
<th>Airplanes</th>
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<tbody>
<tr>
<td>Share of transport fuel consumption</td>
<td>39%</td>
<td>28%</td>
<td>24%</td>
<td>9%</td>
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<td>Fleet size – Millions</td>
<td>130</td>
<td>80</td>
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<td>New – Millions/year</td>
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<td>Median life – Years</td>
<td>17</td>
<td>16</td>
<td>28</td>
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</tr>
</tbody>
</table>

Source: SAIC/MISI

Biggest, fastest savings
Markets: Fuels & Vehicles

Vehicle Needs

- Target to have all new light-duty vehicles being E85-compatible FFVs by 2020
  - This is a significant public policy opportunity

- May also encourage E85+ optimized FFVs to appear on large scale to help drive ethanol transition

- Next generation – Flex Fuel, Plug-in Hybrid Vehicles
30 x 30 Target
Replace 30% of 2004 motor gasoline demand with ethanol by 2030 – 60 billion gallons